the greenhouse. Next implementation steps involve controlling the positioning table and equipment remotely over the Internet.

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CHEMIN: A Mineralogical Instrument for Mars Exploration

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The identification of the types of rocks on Mars that may harbor evidence of present or past life (that is, biomarkers) will require *in situ* mineralogical analysis. In order to establish the conditions under which a rock formed, the identity of each mineral present and its amount must be determined. In terrestrial laboratories, x-ray diffraction and x-ray fluorescence (XRD/XRF) are the techniques of choice for such characterizations.

Recent progress in x-ray technology allows the consideration of simultaneous x-ray diffraction (XRD: mineralogic analysis) and high-precision x-ray fluorescence (XRF: chemical analysis) in systems scaled down in size and power to the point at which they can be mounted on landers or small robotic rovers. The CHEMIN XRD/XRF instrument, which simultaneously collects XRD and XRF data, has been proposed in the past for a variety of solar-system missions and is presently proposed for three separate Mars scout missions, including a precision lander, a penetrator, and a lander equipped with a drill.

NASA was awarded a patent in 1996 (U.S. Patent No. 5,491,738) for the CHEMIN concept. The instrument received a commercial "R&D 100 award" as one of the top 100 innovative technologies of 1998. A SBIR (Small Business, Innovative Research) phase II proposal has been awarded to Moxtek, Inc. to build and commercialize a laboratory version of CHEMIN.

CHEMIN is a charged-coupled device (CCD)-based simultaneous XRD/XRF instrument. The device is designed to characterize the elemental composition and mineralogy of small fine-grained or powder samples. The name CHEMIN refers to the combined CHEmical and MINeralogic capabilities of the instrument.

Diffraction and fluorescence data are obtained simultaneously by operating the CCD in single-photon counting mode. Energy discrimination is used to distinguish between diffracted primary beam photons and fluorescence photons. Diffraction data are obtained in transmission mode, and resolution is presently sufficient on the prototype instrument to allow application of the Rietveld refinement method to the diffraction data. X-ray fluorescence data will be obtained for all elements, $4 < Z < 92$.

A diagram of the proposed CHEMIN flight instrument is shown in figure 1. In operation, the carousel of the instrument (which is the only moving part) is rotated to place one of 40 collection grids in a position to receive a soil sample or a sample of drill cuttings from a rock. The carousel is then rotated to place the grid in the analysis position between the x-ray source and the CCD. A combination of carousel rotation and 1- to 2-millimeter motion along the x-axis allows the entire substrate to be sampled sequentially by the x-ray beam. An intelligent systems program determines the location of sample material suitable for analysis and supervises data collection.

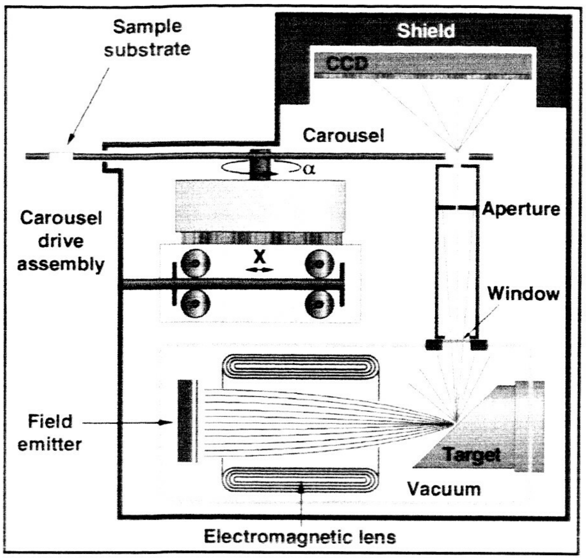

Fig. 1. Cross-sectional diagram of the proposed CHEMIN flight instrument.

A prototype of the CHEMIN instrument has been operable since July 1996. After optimization of the x-ray source collimation, later in 1996, diffraction data of sufficient quality to be used with advanced diffraction data analysis methods such as Rietveld refinement were obtained. Various sample handling systems are presently being pursued, and designs have been proposed for terrestrial use in commercial laboratories, in the International Space Station, and in the proposed Mars Sample Return Handling Facility.

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Sugar-Related Compounds in Meteorites

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A goal of NASA is to understand the origin and evolution of life. Carbonaceous meteorites provide the only record yet available for the laboratory study of organic compounds that were synthesized very early in the solar system and delivered to the planets. Until now, sugars and related compounds (polyols), one of the most critical classes of compounds necessary for all current life forms, had not been definitively identified in extraterrestrial samples. Ribose and deoxyribose, five-carbon sugars, are central to the role of contemporary nucleic acids, deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). Glycerol, a three-carbon sugar alcohol, is a constituent of all known biological membranes. Part of the scientific research performed at Ames is directed toward determining whether or not such compounds are part of the organic content of meteorites. This report describes the results of the search for such compounds.

Results are reported from analysis of water extracts of the Murchison and Murray carbonaceous meteorites. The means of identification of compounds was gas chromatography–mass spectrometry (GC–MS). Compounds were prepared for GC–MS as their trimethylsilyl and/or tertiary butyl-dimethylsilyl derivatives. Present analyses of Murchison and Murray extracts show that a variety of polyols are present in carbonaceous meteorites (figure 1). The identified compounds include a sugar, dihydroxy acetone; sugar-alcohols; sugar mono-acids; sugar di-acids; and "deoxy" sugar acids (or "saccharinic" acids). In general, the compounds follow the abiotic synthesis pattern of other meteorite classes of organic compounds: decreasing abundance with increasing